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CORRELATION OF SCIENCE STUDIES IN SECONDARY SCHOOLS.

IN the discussion of this subject I wish to impose two limitations:

1. *Only the laboratory sciences are referred to.* In most secondary schools a variety of subjects is loosely aggregated under the general name "science." They differ so much among themselves in purpose and method that they should be referred to at least two widely different categories. There are those whose purpose and method are purely informational, subjects about which it is well enough that every intelligent man should be somewhat informed. Physical geography, astronomy, geology, physiology so-called, as mostly taught, all belong to this category, and are not included in the college demand for scientific training. They are necessary and exceedingly helpful subjects, but in the very nature of things cannot be handled in secondary schools other than as purely informational subjects. As such they contain no scientific training whatever, and such claim should not be made for them. In the category of fundamental laboratory sciences are included chemistry, physics, botany and zoölogy. The principles derived from these are applied in the informational subjects referred to above. So far as these four fundamental subjects are studied without the laboratory they are transferred to the informational series and have no value in scientific training. I wish at this point to take issue with the too prevalent statement that the purpose of scientific

training is to teach the methods of the laboratory. The true purpose seems to have been persistently misunderstood. Facts and methods are no more science than words and grammar are literature. Science, concerning itself with facts in their relation, resulting in a formula, cultivates the scientific temper. The student of literature, ancient or modern, is brought into the region of feeling, of what is known as "appreciation," and his ultimate purpose may be broadly called æsthetic. He reads himself into his material and decides what is best in thought. The student of science endeavors to keep himself out of his material, to eliminate the personal equation, to relate his facts so as to include nothing of himself. Personal injection on the one hand and personal elimination on the other represent the ultimate difference in the two cases, and two more complementary kinds of training could not be imagined. This may suggest the educational purpose of science training; not analysis merely, but through analysis to reach a synthesis which shall contain nothing of one's self. It is evident that personal contact with the facts is an essential of such training, and that purely informational work holds no more relation to it than do the old text-books about literary people and the titles of their works to training in literature.

2. *There is presupposed a certain amount of science training in the primary school.* This simply refers to the observation of the ordinary phenomena included under the general head of "nature study."

With these two limitations I wish very briefly to discuss the correlation of science studies in secondary schools. In the outset I would say that the proper sequence of the informational science studies which have been ruled out of this discussion has doubtless given much trouble, but they hold a certain definite relation to the laboratory sciences. Naturally, if geology be taught, it should follow the four fundamentals, or as much of them as may be presented in the course. Physiology, by which is usually meant a study of the anatomy of the human body, with a little physiology thrown in, finds its natural place

after a course in zoölogy. Astronomy certainly holds a definite relation to whatever of mathematics and physics may be taught; and so on. My own personal judgment is, that the less of such subjects in a secondary school the better; but I am willing to recognize the force of a general demand. The time is limited enough, at best, in which to do good work in the fundamentals of education, without trying to inject into our schemes of study an incoherent mass of odds and ends.

Taking up the real laboratory sciences, therefore, chemistry, physics, botany, and zoölogy, it is not at all necessary that any secondary school present all of them in its courses. It is perhaps unwise for many of the schools to attempt a laboratory equipment sufficient for all these subjects. It would usually result in such meager equipment that the real purpose of the work would be in danger of being sacrificed. Where a school can afford it all four laboratories should be represented, but they should be open to election. To compel any student to take work in all these laboratories is as much of an educational fallacy as to permit him to enter none of them.

If the scientific attitude of mind be a large purpose, aside from information, then but two laboratories are necessary, namely, a physical laboratory for chemistry or physics, and a biological laboratory for botany or zoölogy; and nothing less than a year in each of them should count. A school that can afford nothing more should attempt nothing more. If it can afford three laboratories, then, although a biologist, I should say let the third be brought about by subdividing the physical laboratory into its constituent elements, physics and chemistry, and retain but one biological laboratory, which shall be devoted to either botany or zoölogy. To my mind the correlation of subjects is simple enough. We start with the proposition that laboratory science is to be taught, and to be taught with its real purpose in view. In considering the field of scientific subjects we find but four that seem fundamental and capable of proper laboratory treatment in secondary schools. Upon examining these four we discover that they are naturally thrown into two groups, that differ from each

other in the nature of the material, the problems presented, the method of work, the certainty of conclusions. One set is the very embodiment of exactness; the other is less exact but calls for larger powers of interpretation. In the largest sense, one measures, the other observes; one deals with matter, the other with life as it manifests itself in matter. While both have much in common each has its special effect on the mind of the student. These two effects, therefore, represent to us the result of the last analysis of the educative work of the laboratory sciences. It means that but two of them are absolutely necessary, but that these two must have contact sufficient to produce a sensible result. It means that if one or two more are added, it is by way of cumulative effect rather than specific effect. This makes the minimum two years, one devoted to a physical science, and one to a biological science. The sequence of these two subjects is naturally the next point to consider. Just here my conclusions seem to be at variance with the general custom, and also with distinguished opinion, such as is expressed, for example, in the "Report of the Committee of Ten." I find it to be the usual custom to introduce the biological subject or subjects early in the course, and to defer the physical sciences to the later years. If plants and animals are simply to be studied as things to be named, a process which has been likened to chasing a woodchuck into its hole, there is nothing but the hole to show for the work; or if, what is far better, they are to be studied simply as forms, facts which are obtained by *post mortem* examination, then I grant that the biological sciences hold no relation to the physical, and can be put wherever it happens to be the most convenient. Such, however, is not the conception at present of the proper study of plants and animals. They are living things, and any contact with them which leaves out of view the processes of living is worse than the play of Hamlet with Hamlet left out. They are not merely living things with multifarious internal physical and chemical processes, but they hold definite relations to heat, light, gravity, etc., as well as the chemical compounds, in their environment. To have even an elementary appreciation of plants or animals in their life activities, one must bring to the

study at least some elementary conception of the general principles of chemistry and physics, such conceptions of both as can be obtained from a year's study of either. If there be any natural sequence, therefore, between the physical and biological sciences, it is certainly one that places the study of matter and its laws first, and afterwards the study of life as it manifests itself in matter. I should certainly place the biological subjects late in the course, provided suitable primary work has been done. If this has not been done, then the biology of the secondary school begins upon a plane that I have not taken into consideration.

In case both chemistry and physics are taught, I take it that the much discussed question of their sequence has been settled as a matter of convenience rather than of logic. Logically physics should precede chemistry; but practically it demands so much mathematics that the reverse sequence is a common one. I do not regard this, however, as a matter of large importance when compared with the sequence of the biological and physical sciences. The same kind of discussion might be taken up concerning botany and zoölogy in case both are to be taught, without any such logic in the situation, it is true, but fully as unessential.

My conception of a well-equipped secondary school in which the sciences are presented in a strictly coherent and purposeful way is one in which the four laboratories are represented, each equipped for two years of work; in which each student is required to take at least two years of science, one of which must be a physical, the other a biological science; in which a student in any laboratory can have the opportunity of a second year in the same laboratory; in which physics shall be placed at the beginning of the course, and the other three introduced afterwards either in sequence or two of them simultaneosly. Such are merely general principles, which would need adaptation to all sorts of conditions. No inflexible scheme is feasible, but teachers are supposed to be able to adapt general principles to any set of conditions. The only thing in the whole situation that cannot be adapted is the poorly equipped teacher.

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